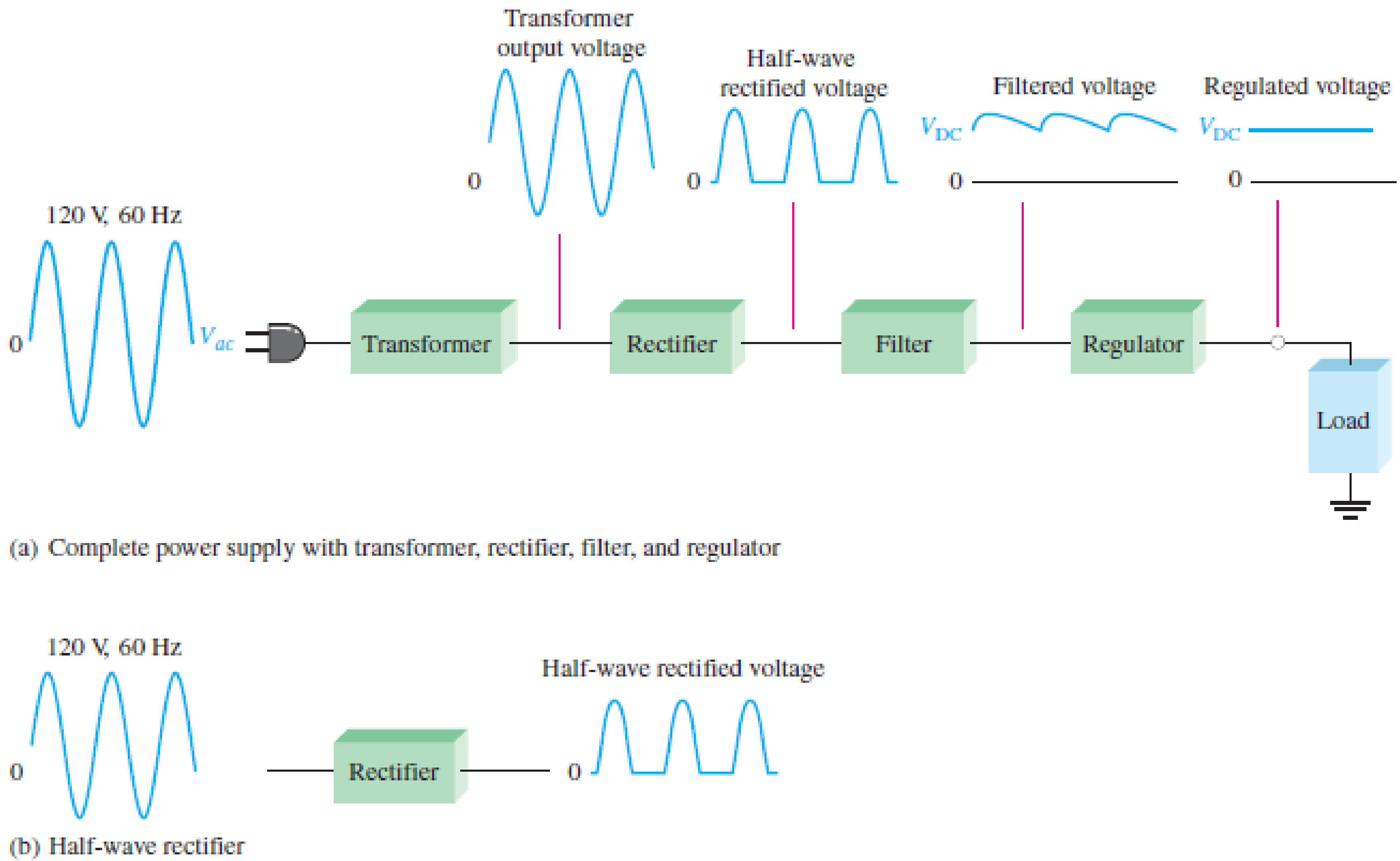
# Crystal Diode Rectifiers

## Half Wave Rectifier

# The Basic DC Power Supply

- All active electronic devices require a source of constant dc that can be supplied by a battery or a dc power supply. The dc power supply converts the standard 120 V, 60 Hz ac voltage available at wall outlets into a constant dc voltage. The dc power supply is one of the most common circuit.
- The voltage produced is used to power all types of electronic circuits including consumer electronics (televisions, DVDs, etc.), computers, most laboratory equipment etc.
- A basic block diagram of the complete power supply is shown in Figure below

# Block diagram of a dc power supply with a load and a rectifier.



- A **transformer** changes ac voltages based on the turns ratio between the primary and secondary.
- If the secondary has more turns than the primary, the output voltage across the secondary will be higher and the current will be smaller.
- If the secondary has fewer turns than the primary, the output voltage across the secondary will be lower and the current will be higher.
- If the number of turns are same on both side the transformer is then used for isolation purpose.

- The **rectifier** can be either a half-wave rectifier or a full-wave rectifier. The rectifier converts the ac input voltage to a pulsating dc voltage, called a half-wave rectified voltage, as shown in Figure (b).
- The **filter** eliminates the fluctuations in the rectified voltage and produces a relatively smooth dc voltage.
- The **regulator** is a circuit that maintains a constant dc voltage despite of variations in the input line voltage or in the load.

# Important Terms

**(i) Forward current.** It is the current flowing through a forward biased diode. If this value is exceeded, the diode may be destroyed due to excessive heat.

**(ii) Peak inverse voltage.** It is the maximum reverse voltage that a diode can withstand without destroying the junction.

$$PIV = V_{in}$$

**(iii) Reverse current or leakage current.** It is the current that flows through a reverse biased diode. This current is due to the minority carriers. Under normal operating voltages, the reverse current is quite small. Its value is extremely small ($< 1\mu$ A) for silicon diodes but it is appreciable ($\approx 100\ \mu A$) for germanium diodes.

# Crystal Diode as a Rectifier

- A.c. input voltage to be rectified, the diode and load RL are connected in series.
- During the positive half-cycle of a.c. input voltage, the arrowhead becomes positive w.r.t. bar. Therefore, diode is forward biased and conducts current in the circuit.
- The result is that positive half-cycle of input voltage appears across $R_L$ as shown.
- However, during the negative half-cycle of input a.c. voltage, the diode becomes reverse biased because now the arrowhead is negative w.r.t. bar. Therefore, diode does not conduct and no voltage appears across load $R_L$.
- The result is that output consists of positive half-cycles of input a.c. voltage while the negative half-cycles are suppressed.

In this way, crystal diode has been able to do rectification i.e. change a.c. into d.c. It may be seen that output across $R_L$ *is pulsating d.c.*

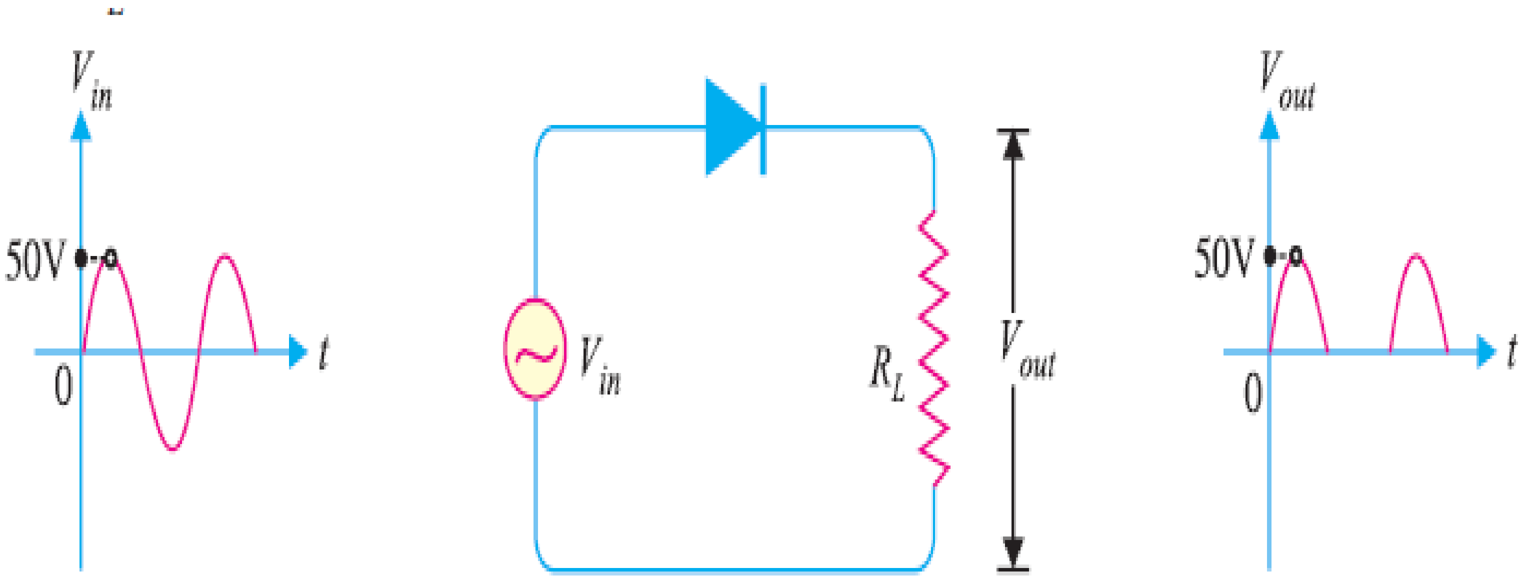



Fig: 01 Crystal Diode as a Rectifier

# Resistance of Crystal Diode

- A forward biased diode conducts easily whereas a reverse biased diode practically conducts no current.
- It means that forward resistance of a diode is quite small as compared with its reverse resistance.
- 1. Forward resistance. The resistance offered by the diode to forward bias is known as forward resistance.

✓ Accordingly; this resistance is of two types, namely;

1) d.c. forward resistance

2) a.c. forward resistance.

(*1) d.c. forward resistance*

- It is the opposition offered by the diode to the direct current. It is measured by the ratio of d.c. voltage across the diode to the resulting d.c. current through it.

(2) a.c. forward resistance. It is the opposition offered by the diode to the changing forward current.

- It is measured by the ratio of change in voltage across diode to the resulting change in current through it i.e.

  a.c. forward resistance, $r_f$ = Change in voltage across diode / Corresponding change in current through diode

(3) Reverse Resistance:

- The resistance offered by the diode to the reverse bias is known as reverse resistance.
- It can be d.c. reverse resistance or a.c. reverse resistance depending upon whether the reverse bias is direct or changing voltage. Ideally, the reverse resistance of a diode is infinite.
- However, in practice, the reverse resistance is not infinite because for any value of reverse bias, there does exist a small leakage current.

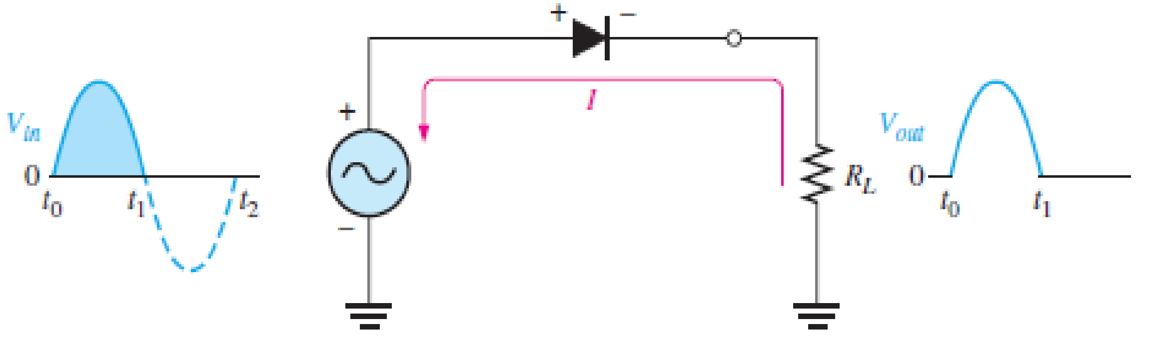
# Crystal Diode Rectifiers

- There are many applications (e.g. electronic circuits) where d.c. supply is needed.
- When such a d.c. supply is required, the mains a.c. supply is rectified by using crystal diodes. The following two rectifier circuits can be used :

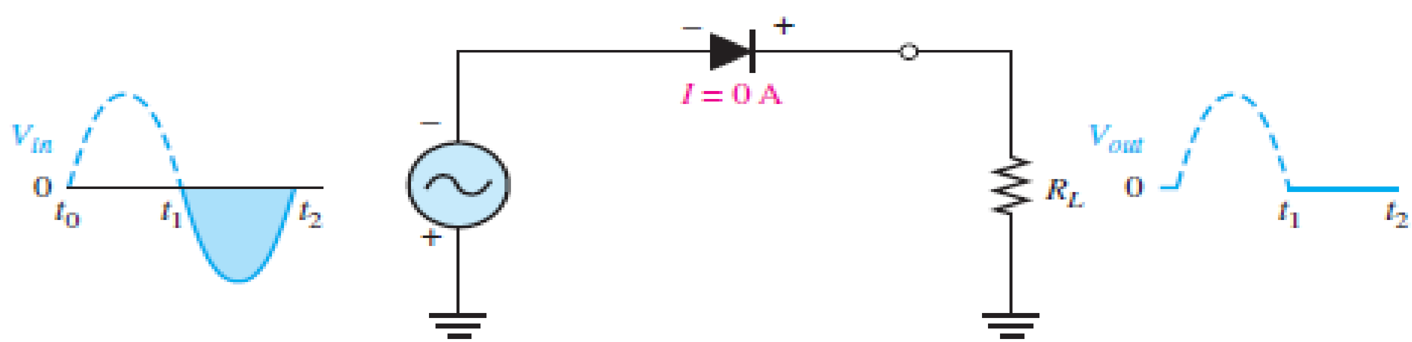
- (i) Half-wave rectifier (ii) Full-wave rectifier

# Half-Wave Rectifier Operation

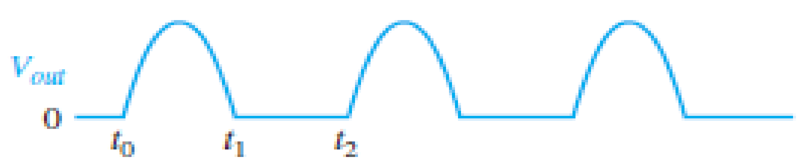
- A diode is connected to an ac source and to a load resistor, $R_L$, forming a half-wave rectifier.
- Keep in mind that all ground symbols represent the same point electrically.
- When the sinusoidal input voltage ($V_{in}$) goes positive, the diode is forward-biased and conducts current through the load resistor, as shown in Fig: part (a).
- The current produces an output voltage across the load $R_L$, which has the same shape as the positive half-cycle of the input voltage.



- When the input voltage goes negative during the second half of its cycle, the diode is reverse-biased. There is no current, so the voltage across the load resistor is 0 V, as shown in Figure (b).
- The net result is that only the positive half-cycles of the ac input voltage appear across the load. Since the output does not change polarity, it is a pulsating dc voltage with a frequency of 60 Hz, as shown in part (c).




(b) During the negative alternation of the input voltage, the current is 0, so the output voltage is also 0.




(c) 60 Hz half-wave output voltage for three input cycles

# Advantages of Half wave rectifier

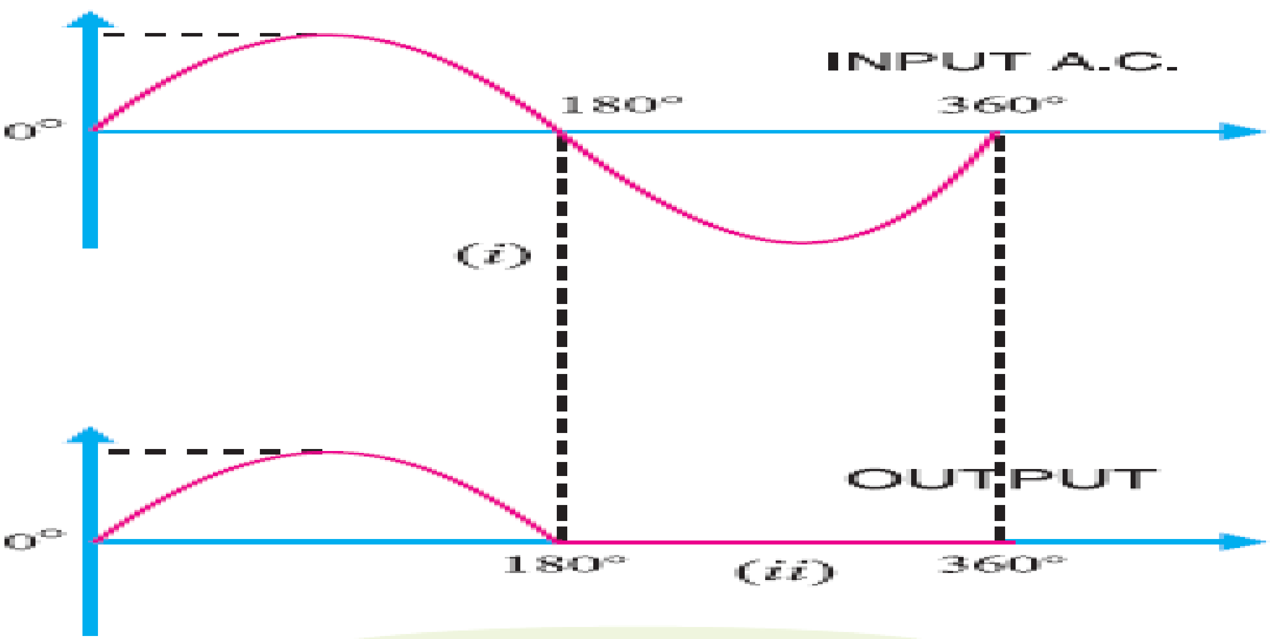
- Due to less no: of components used, they are cheaper to setup and construct.

Disadvantages :

- The a.c. supply delivers power only half the time. Therefore, the output is low.
- The output current obtain is not purely DC and there are a lot of ripples in it.
- The Half wave rectifier only allows half cycle through and the other half cycle is wasted this leads to power loss.

# Output Frequency of Half-Wave Rectifier

- The output frequency of a half-wave rectifier is equal to the input frequency.
- In Fig.(1) ,the a.c. input voltage repeats the same wave pattern over 0° – 360°, 360° – 720° and so on. In Fig. (ii), the output waveform also repeats the same wave pattern over 0° – 360°, 360° – 720° and so on.
- This means that when input a.c. completes one cycle, the output halfwave rectified wave also completes one cycle.
- In other words, the output frequency is equal to the input frequency i.e. $f_{out} = f_{in}$



# Efficiency of a Half Wave Rectifier

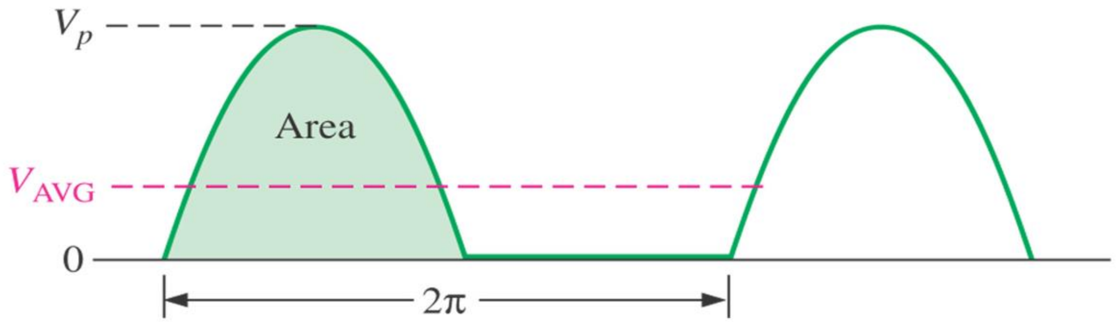
- The ratio of DC power output to the applied AC power input is known as Rectifier Efficiency

$$\text{Rectifier Efficiency, } \eta = \frac{\text{DC power output}}{\text{AC input power}}$$

Max efficiency of a half wave rectifier is 40.6%.

# Average Value of a Half Wave Rectifier

- Average value of a half wave rectifier is a value that is measured on a DC voltmeter.
- The area under the curve over a full cycle and then dividing by 2π, is known as average value of the signal.




- The average value of a half wave rectifier output is approximately 31.8% of the peak input voltage Vp.
- $V_{avg} = Vp/\pi$

# Derivation

- The average value of a half-wave rectified sine wave is the area under the curve divided by the period (2π). The equation for a sine wave is

$$v = V_p \sin\theta$$

$$V_{\text{AVG}} = \frac{\text{area}}{2\pi} = \frac{1}{2\pi}\int_0^{\pi} V_p \sin\theta \, d\theta = \frac{V_p}{2\pi}(-\cos\theta)\Big|_0^{\pi}$$

$$= \frac{V_p}{2\pi}[-\cos\pi - (-\cos 0)] = \frac{V_p}{2\pi}[-(-1) - (-1)] = \frac{V_p}{2\pi}(2)$$

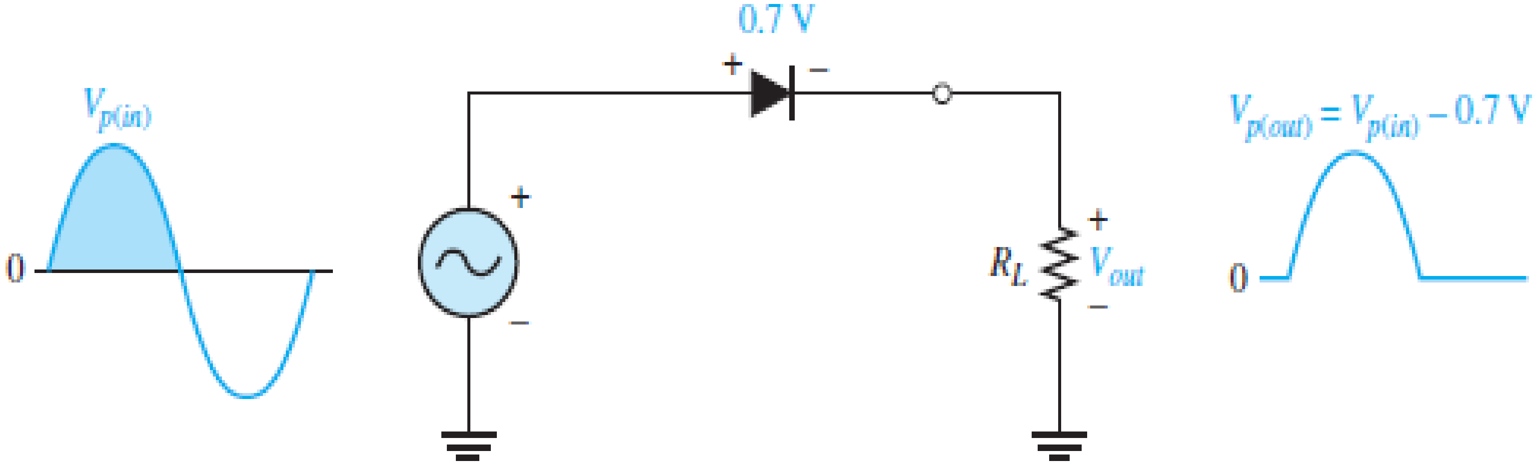
$$V_{\text{AVG}} = \frac{V_p}{\pi}$$

# Effect of Barrier Potential on Half Wave Rectifier Output

- When the practical diode model is used with the barrier potential of 0.7 V taken into account, the input voltage must overcome the barrier potential before the diode becomes forward-biased during the positive half-cycle.
- This results in a half-wave output with a peak value that is 0.7 V less than the peak value of the input, as shown in Figure below

- And the expression is given as

$$Vp(out) = Vp(in) - 0.7\text{ V}$$

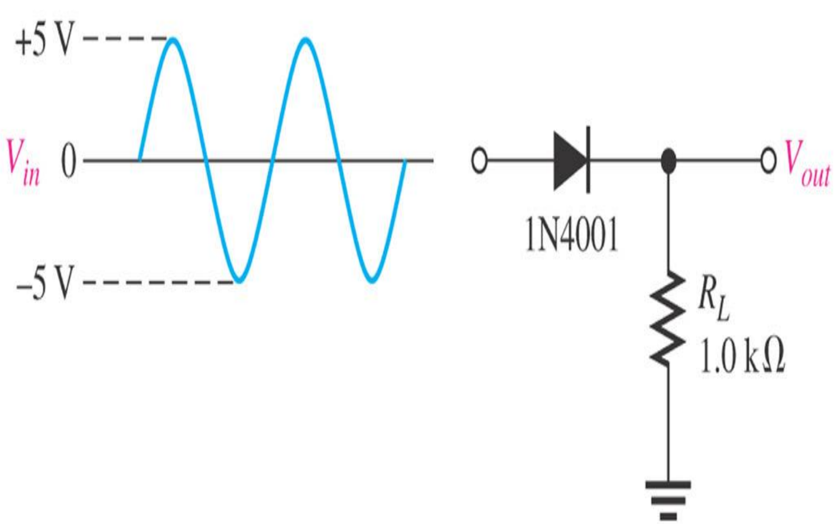


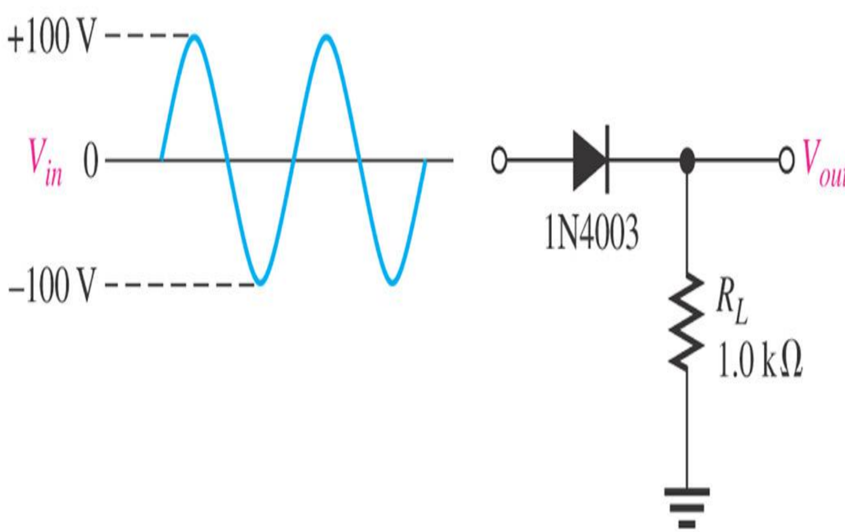
# Example

1. The applied input a.c. power to a half-wave rectifier is 100 watts. The d.c. output power obtained is 40 watts. What is the rectification efficiency ?

2. What is the average value of the half-wave rectified voltage if $V_{IN}$ is 100V?

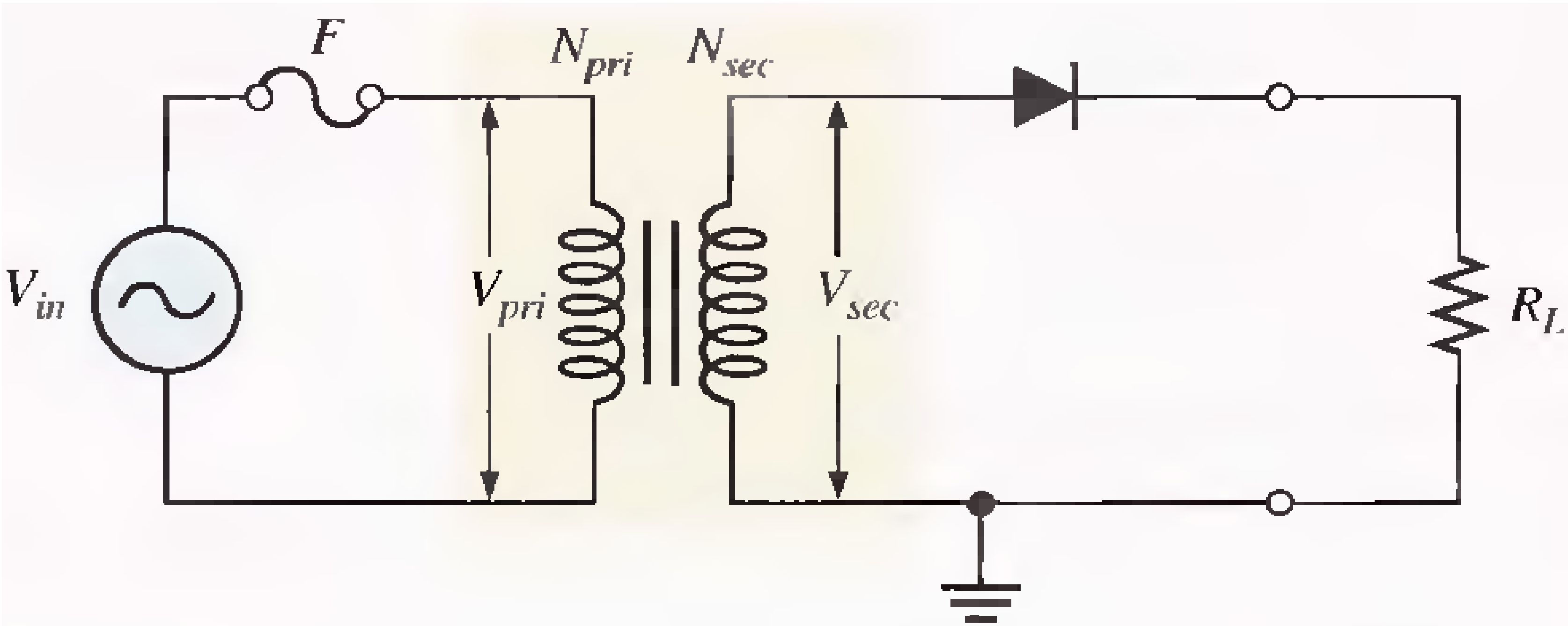
3. What will be the output voltage for a rectifier diodes in the following diagrams?



# Half-Wave Rectifier with Transformer-Coupled Input Voltage

- Transformer is often used to couple the input from ac source to the rectifier.
- Transformer coupling provides two advantages
- Transformer allows the source voltages to be stepped up or stepped down as needed.
- Secondly, the ac source is electrically isolated from the rectifier; thus preventing a shock hazard in the secondary circuit.



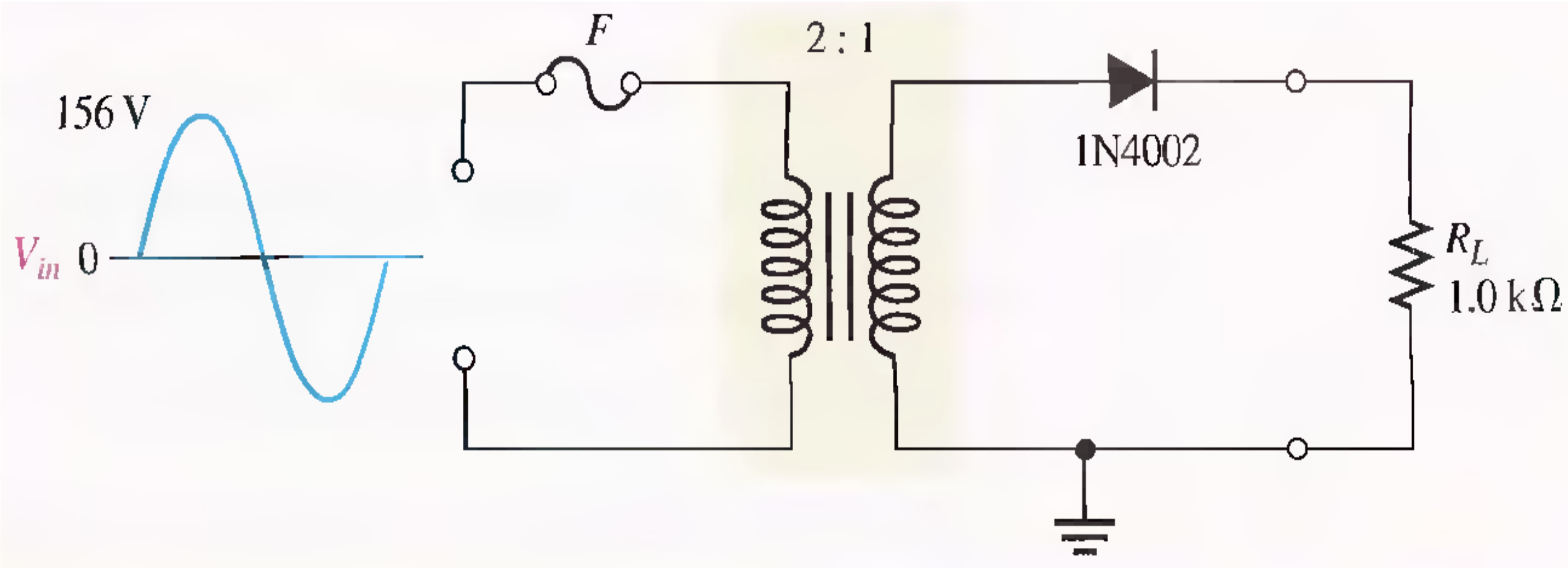

$$\frac{V_{SEC}}{V_{PRI}} = \frac{N_{SEC}}{N_{PRI}} = \frac{I_{PRI}}{I_{SEC}} = n = \text{Transformer Ratio}$$

$$V_{P\,(Out)} = V_{P\,(Sec)} - 0.7\text{ V}$$

$$PIV = V_{P\,(Sec)}$$

# Example

- Determine the peak value of the output voltage, if the turn ratio is 0.5.




**[156 V, 78 V, 77.30 V]**

# Example

- **(a)** Determine the peak value of the output voltage if $n$=2 and Vp(in)= 312V.
- **(b)** What is the PIV across the diode?
- **(c)** Describe the output voltage if the diode is turned around